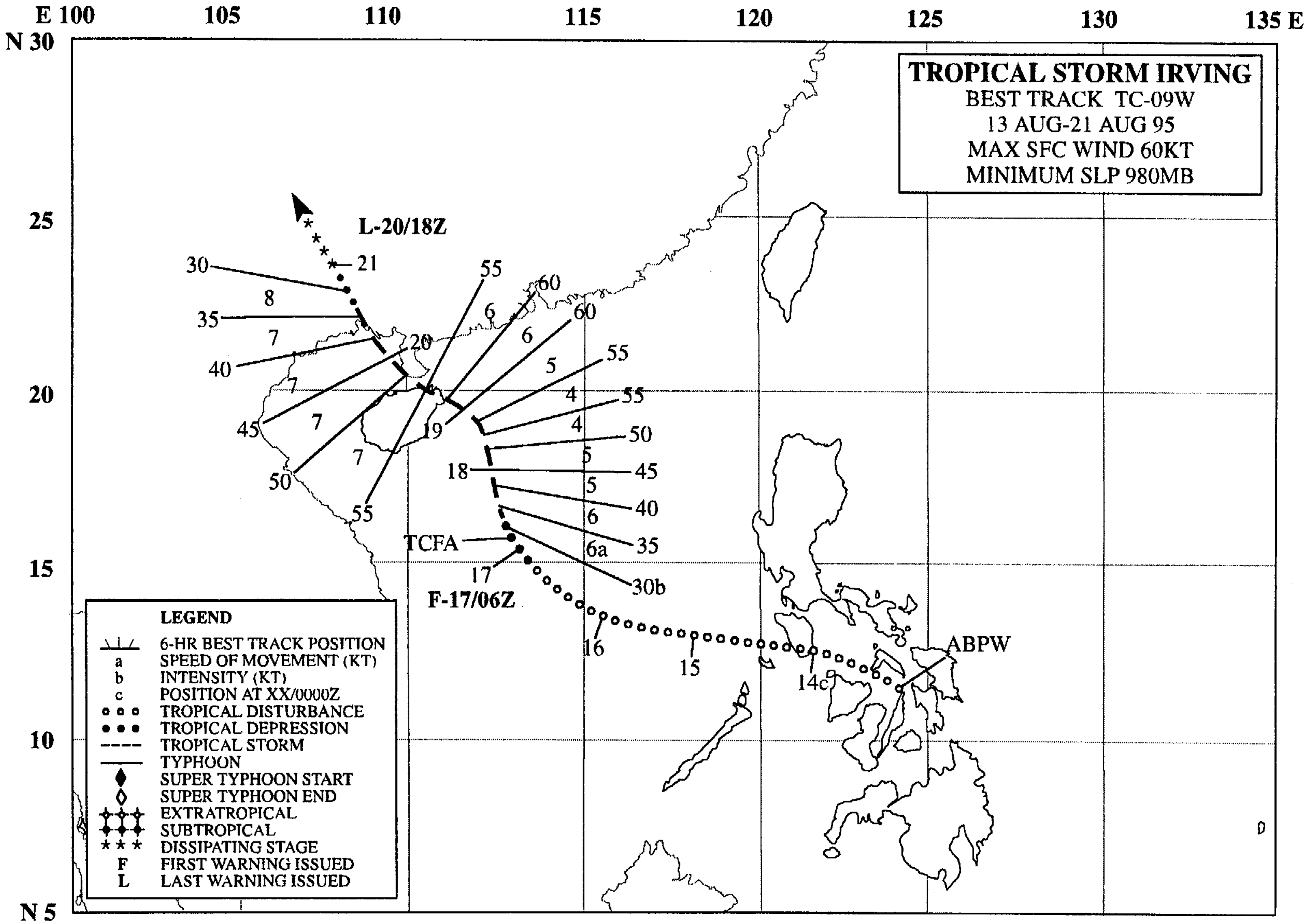
TROPICAL STORM IRVING
BEST TRACK TC-09W
13 AUG-21 AUG 95
MAX SFC WIND 60KT
MINIMUM SLP 980MB
E 100
105
110
115
120
125
130
135 E
N 30
25
20
15
10
N 5
L-20/18Z
F-17/06Z
TCFA
ABPW
21
19
18
17
16
15
14c
30
35
40
45
50
55
60
6a
30b
LEGEND
6-HR BEST TRACK POSITION
a SPEED OF MOVEMENT (KT)
b INTENSITY (KT)
c POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
SUBTROPICAL
DISSIPATING STAGE
F FIRST WARNING ISSUED
L LAST WARNING ISSUED

TROPICAL STORM IRVING (09W)

I. HIGHLIGHTS

The second of eight tropical cyclones to form in, or near, the South China Sea during 1995, Irving was very small. Isolated in an otherwise relatively cloud free region of the South China Sea, Irving maintained a very small CDO under which microwave imagery indicated the presence of an eye.

II. TRACK AND INTENSITY

As Tropical Storm Helen (08W) was moving inland over southern China, an area of deep convection associated with the monsoon trough consolidated near the central Philippines on 12 August. On 13 August, synoptic data indicated that a weak low-level circulation center accompanied this tropical disturbance, which was mentioned on the 130600Z August Significant Tropical Weather Advisory. For the next few days, the tropical disturbance moved slowly westward in the South China Sea and showed no signs of further intensification. Visible satellite imagery obtained at first light on the morning of 17 August revealed increased organization of the convective cloud lines, and JTWC issued a Tropical Cyclone Formation Alert at 170100Z. Later that afternoon, visible satellite imagery indicated a further increase in the definition of the low-level circulation center, and the JTWC issued the first warning on Tropical Depression 09W, valid at 170600Z. The deep convection of Tropical Depression 09W rapidly consolidated into a small area very close to the low-level circulation center while, at the same time, other areas of deep convection away from the low-level circulation center subsided. The formation of this small CDO led to the upgrade of Tropical Depression 09W to tropical storm intensity at 171200Z August.

As Irving moved northward toward Hainan Island, it retained its small CDO. Microwave imagery at 172121Z (Figure 3-09-1) indicated the presence of an eye. A visible image two hours later showed that the eye was obscured (Figure 3-09-2). The intensity estimates of Irving gradually increased (based on its persistent CDO, more

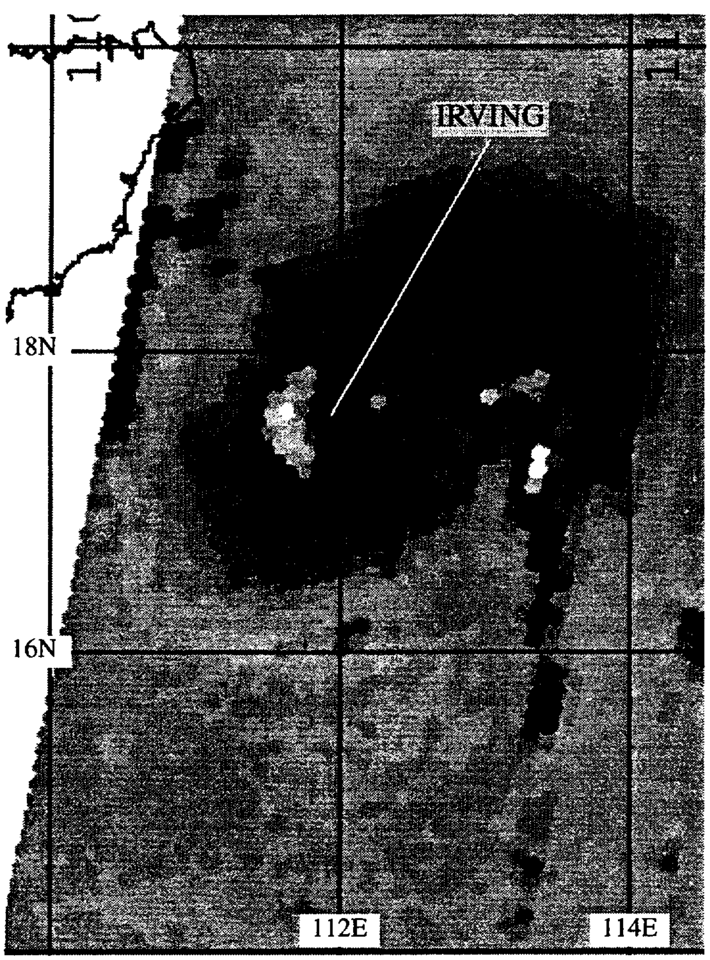

Figure 3-09-1 A small eye is revealed by microwave imagery under the dense cirrus overcast of Irving's small CDO (172121Z August SSM/I 85 GHz DMSP imagery).

tightly curved low-level cloud lines, and better organized cirrus outflow streamers), and at 190000Z it peaked at 60 kt (31 m/sec) (Figure 3-09-3). Moving northwestward, Irving grazed the northeastern tip of Hainan island, crossed the southern end of the Luichow peninsula, and moved inland into southern China near the city of Quinzhou on 20 August. The JTWC issued the final warning, valid at 201800Z August, as Irving dissipated over land.

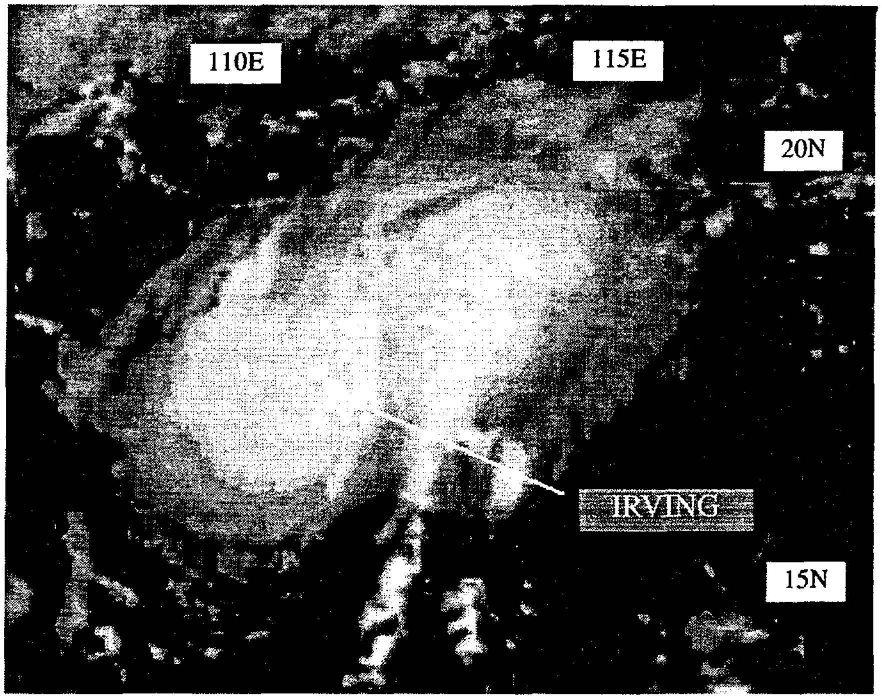

Figure 3-09-2 Cirrus overcast obscures the small eye that appears in Figure 3-09-1 (172331Z August visible GMS imagery).

III. DISCUSSION

a. *Tropical cyclone size: the "midget" tropical cyclone*

Tropical Storm Irving was one of the smallest tropical cyclones of 1995 — only Tropical Depression 22W was smaller. In fact, from the perspective of the size of Irving's satellite-observed cloud shield (including the CDO and curved cirrus outflow streamers), there are few tropical cyclones in recent years that have been as small. Since 1990, only Cecil (1990), Ellie (1991), Zelda (1991), and Ofelia (1993) have been of similar size.

Tropical cyclones of very small size have caught the attention of forecasters and researchers for many years. The terminology used to address very small tropical cyclones still has not been resolved. One of the first written studies of very small typhoons was by Arakawa (1952). Arakawa wrote of very small typhoons that had struck Japan by complete surprise. He called such typhoons, Mame-Taifu (literally, "bean" typhoon; figuratively "midget" typhoon). Dr. C.E. Palmer, one of the meteorologists working in the Marshall Islands during the years of atomic testing by the United States, corresponded with Arakawa on his (Palmer's) observations of very small storms of typhoon intensity occurring in the Marshalls. During September 1966, a reconnaissance flight passed through an extremely intense, but incredibly small hurricane (Inez) in the Caribbean. This hurricane was so small that two scientists working with the data from the flight into Inez (Hawkins and Rubsam 1967) proposed that such storms be called "micro-hurricanes". However, the preferred designation for very small tropical cyclones in the western North Pacific remains Arakawa's "midget".

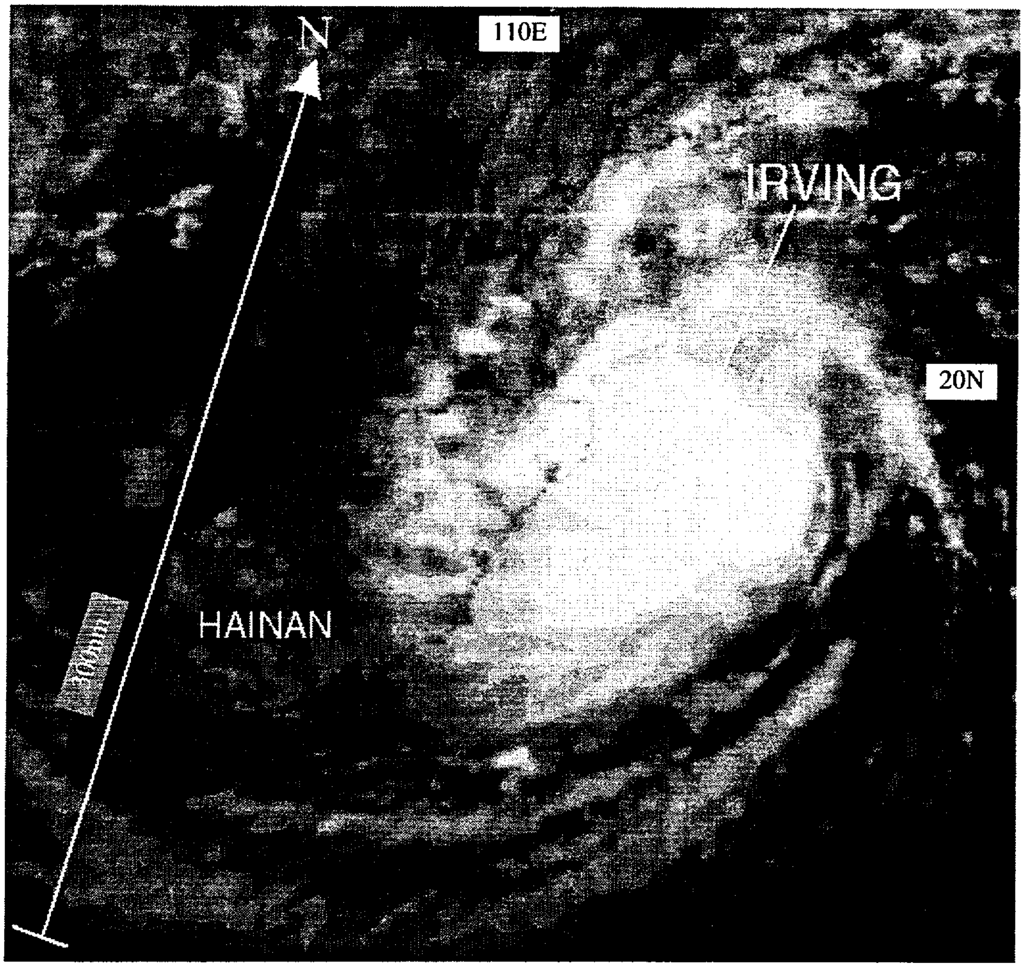

Figure 3-09-3 Tropical Storm Irving at its peak intensity of 60 kt (31 m/sec) (190231Z August visible GMS imagery).

Tropical cyclone size is a very difficult parameter to objectively measure. Brand (1972) classified a tropical cyclone as "very small" if the mean radius to the outer-most closed isobar (ROCI) was two degrees (120 nm, 222 km) of great circle arc (GCA) or smaller. Both the terms "very small" and the term "midget" are used on JTWC bulletins and in the research community, however, the term "midget" is nowhere officially defined (see Appendix A, where herein the size categories of tropical cyclones are: very small, small, average, large, and very large — and are based upon the ROCI). Determining the mean ROCI of tropical cyclones is difficult. This is especially true of tropical cyclones in the western North Pacific that are embedded within larger monsoonal low pressure areas, and where synoptic reports are sparse. After examining recent "midget" tropical cyclones, Guard and Lander (1995) suggest that the satellite cloud signature be used as the primary tool to identify "midget" tropical cyclones. Cloud features used to identify a midget tropical cyclone include:

(1) a CDO, or eyewall plus eye, that does not exceed 90 nm in diameter,

(2) no bands of deep convection more than 120 nm from the low-level center,

(3) a conspicuous lack of low-level cloud lines away from the cover of the central cirrus canopy,

(4) central convection that is often isolated in an otherwise relatively cloud free region,

(5) anticyclonically curved cirrus outflow streamers may be well-organized, but do not extend more than 180 nm from the central convection in any direction.

In addition to the aforementioned satellite-observed characteristics, a structural characteristic found by Lander and Guard (1996) to be typical of the midget tropical cyclone is a rapid drop-off of the wind from the radius of maximum wind outward.

Typical of many "midget" tropical cyclones, Irving lacked peripheral rainbands, and synoptic data indicated that the highest winds were concentrated extremely close to the center. In fact, while it was over the South China Sea, if it were not for detection by satellite, it is doubtful that this tropical cyclone would have ever been detected. Even with detection of Irving by satellite, its intensity was difficult to diagnose. The rapid, and early, formation of Irving's CDO — and its very small size — did not lend itself well to Dvorak enhanced infrared analysis, which requires that the intensity of a tropical cyclone must have become at least 55 kt (28 m/sec) 12 hours before the embedded center technique can be applied. Microwave imagery showing a cirrus covered eye embedded in Irving's small CDO was helpful in supporting the warning intensity of 60 kt (31 m/sec).

b. *Inability of numerical models to analyze and maintain midget tropical cyclones*

Because of their very small size, "midget" tropical cyclones tend not to be analyzed by numerical products. Further, a "midget" tropical cyclone tends to weaken in the forecast and lose its identity as a distinct vortex. These shortcomings of the dynamic guidance are reflected in the following excerpts from the Deputy Director's unofficial log during the development of Irving:

"...Warning # 01: 170900 ... [Irving] should continue to [intensify] in the forecast period. NOGAPS does not have the circulation. ..."

"...Warning # 02: 171500 ... Aids are confusing showing a scatter from west to north. NGPS has no vortex to track...."

"...Warning # 03: 172100 ... NOGAPS model progs are now in fairly good agreement. N to NNWward, slow. ... However it [NOGAPS] doesn't hold the circulation. NGPS therefore still having problems...."

IV. IMPACT

No reports of significant damage or injuries were received.